Cold Atom Laboratory

The Coldest Spot In The Known Universe

Cold Atom Laboratory Instrument Status

Fundamental Physics Workshop

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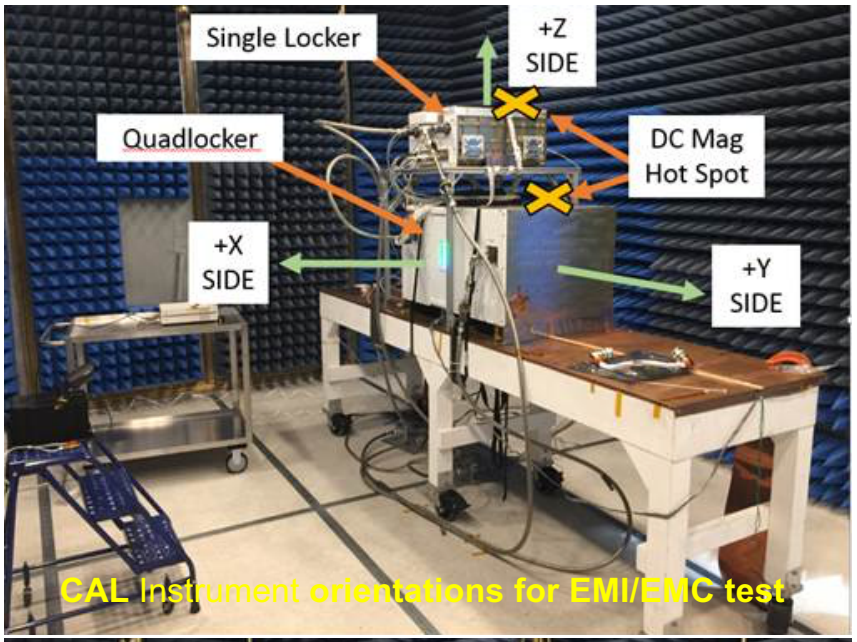
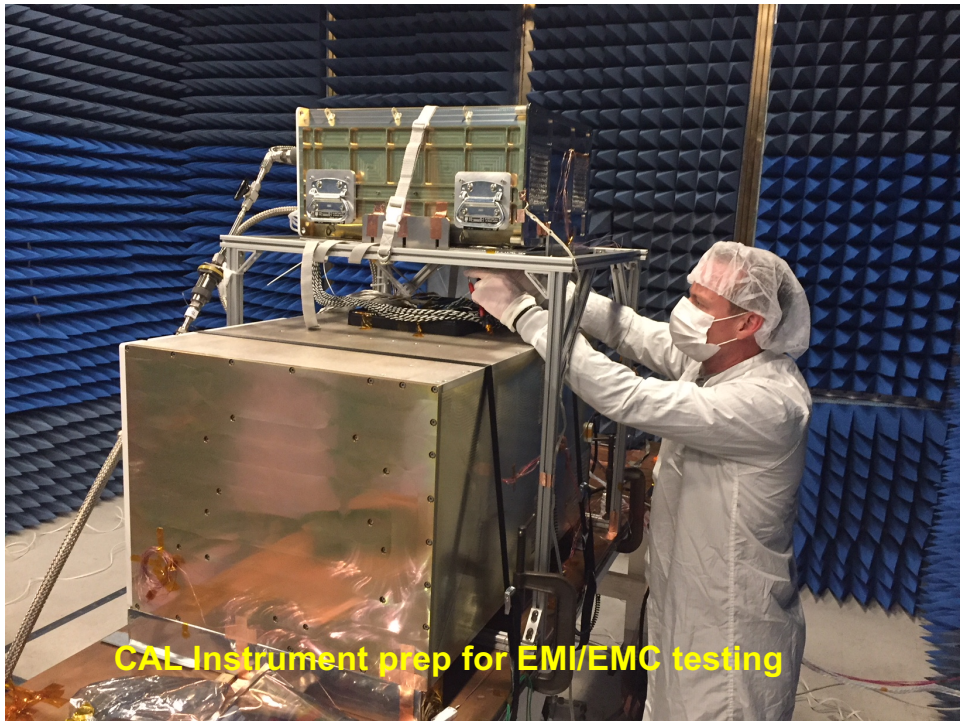
Meet the Cold Atom Lab

EMI/EMC Testing

- Completed the EMC testing campaign on November 2, 2017.
  - Successfully conducted Bonding, DC Magnetics, Radiated Emission AC Magnetics, Electric Field Radiated Emissions, Electric Field Radiated Susceptibility, Isolation Measurements, Ambient, Susceptibility testing



CAL Instrument orientations for EMI/EMC test

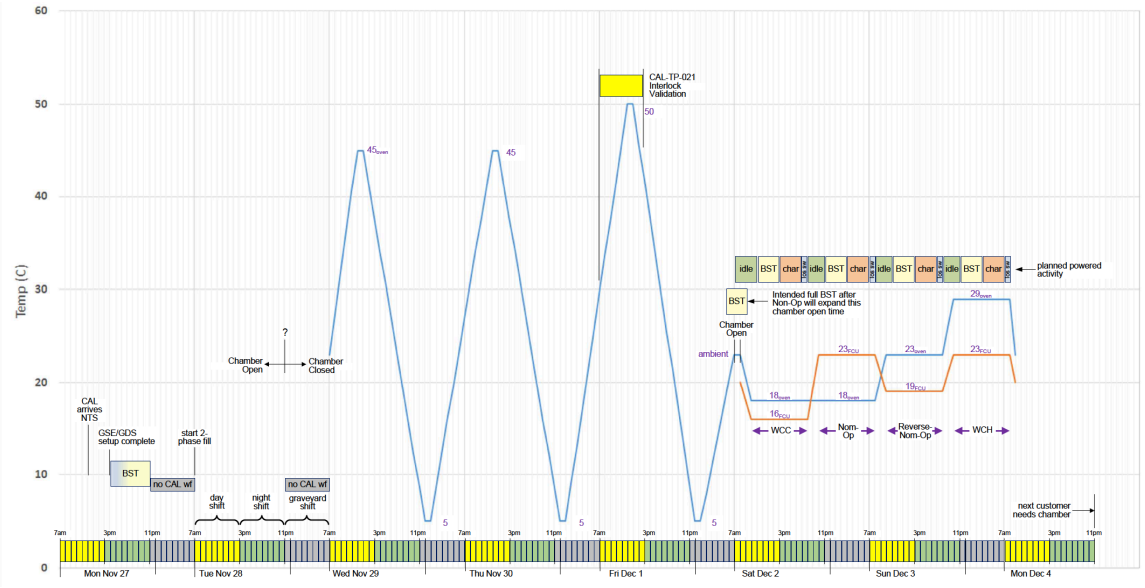

CAL Instrument prep for EMI/EMC testing


CAL Instrument AC Magnetics test setup

System Thermal Test

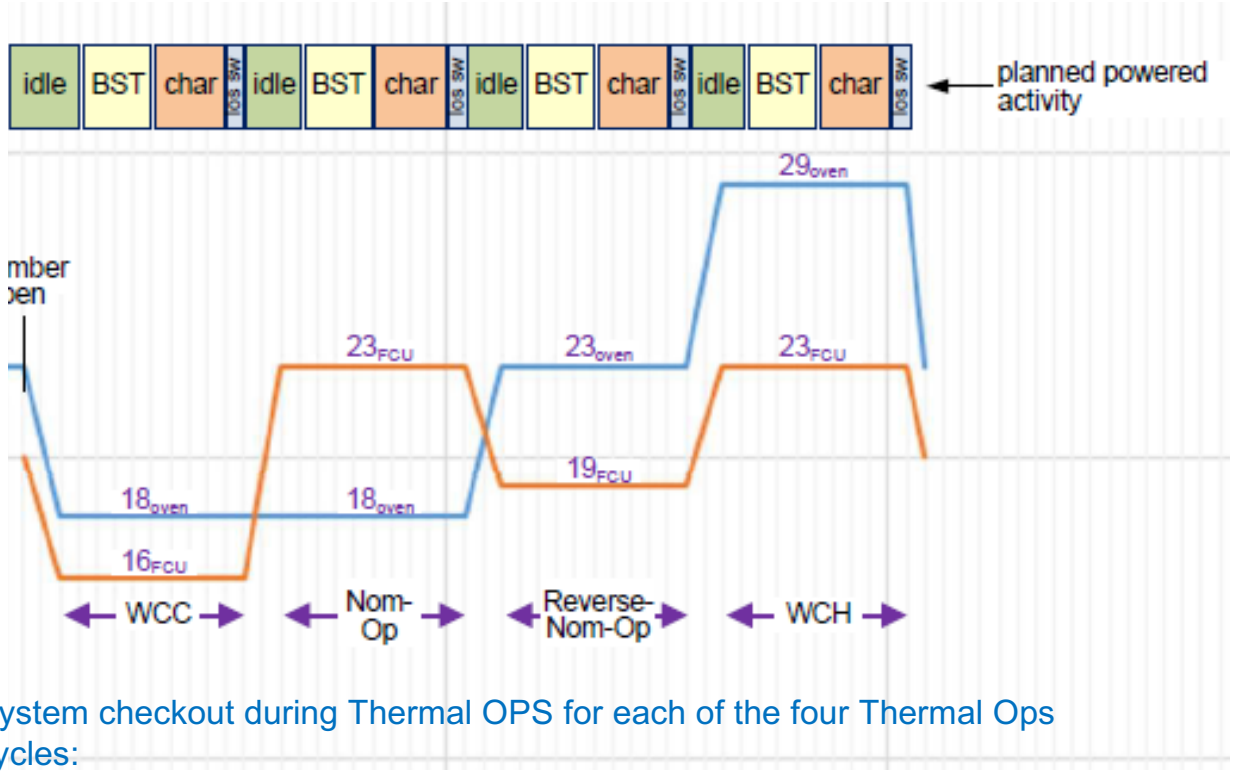
System Plan for Thermal Environments

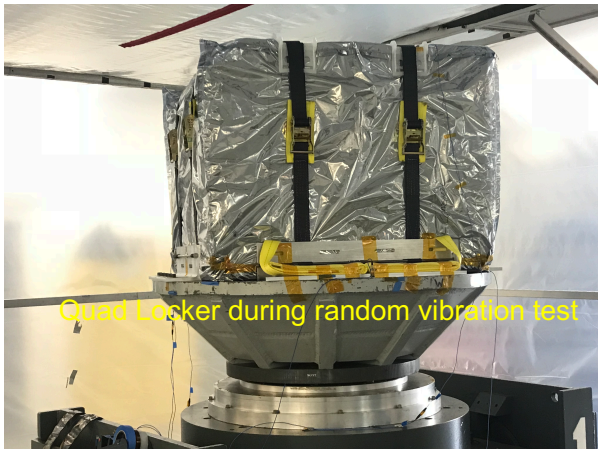
After completion of Non-Operational thermal cycles, experienced two anomalies during post test BST

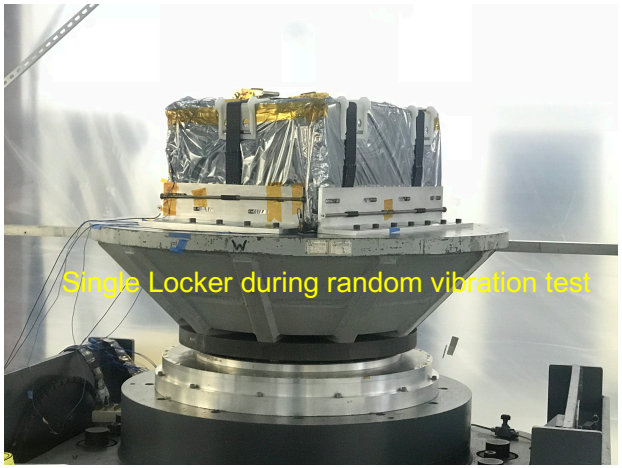


Environmental Testing

- Successfully completed the environmental testing campaign at National Technical Systems (NTS) on February 6, 2018.
  - Completed the random vibration for the Quad Locker and for the Single Locker in the XY and Z directions.
  - Completed the thermal cycling at four different thermal characterization intervals.




Quad Locker during random vibration test

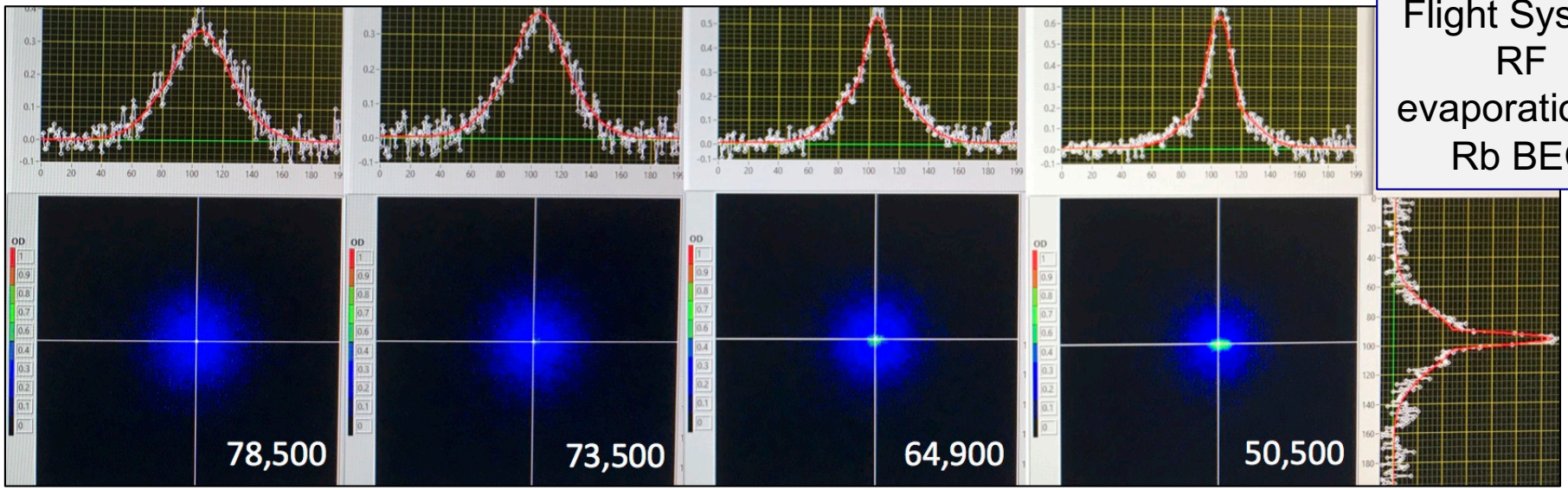

Single Locker during random vibration test

System checkout during Thermal OPS for each of the four Thermal Ops cycles:

- Worst Case Cold (18℃ Air, 16℃ Water)
- Op T1 (18℃ Air, 23℃ Water)
- Op T2 (23℃ Air, 19℃ Water)
- Worst Case Hot (29℃ Air, 23℃ Water)

Final Performance Testing: Rubidium

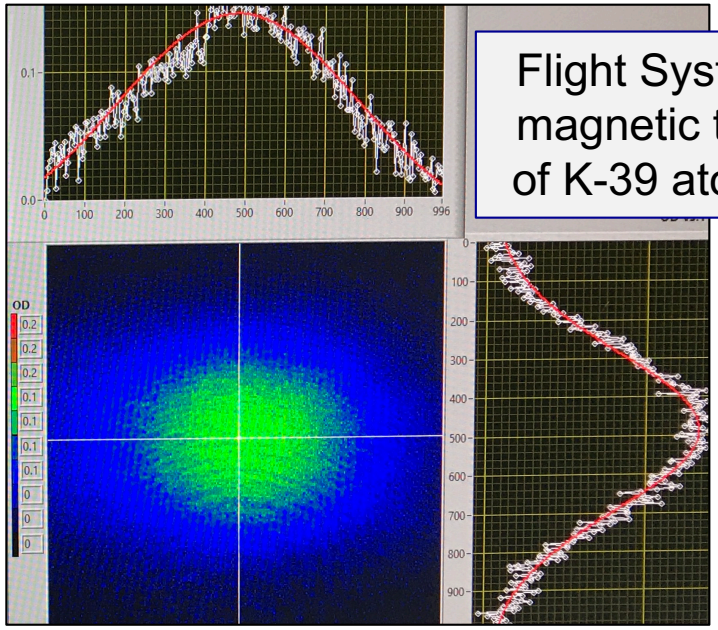
- Successfully completed Final Performance testing on April 3, 2018.
- Robust Rb laser locks, Rb MOTs, magnetic traps, and imaging
- Rb BECs produced routinely in Flight System
- Verified Rb atom number requirement: onset of condensation ~80k atoms
- Verified microwave evaporation to BEC in science module
- Demonstrated microwave evaporation functionally in Flight System at most sensitive stage
- Tuning optimal microwave performance to continue in EMTB and during Flight System's commissioning phase



Flight System RF evaporation of Rb BEC

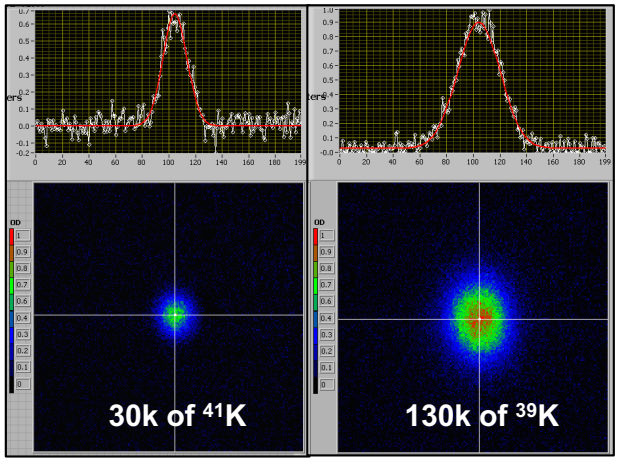
Final Performance Testing: Potassium

- Robust K laser locks, K-39 MOTs, magnetic traps and imaging
- Flight system producing repeatable K-39 magnetically transported traps
- Verified K-39 and K-41 sympathetically cooled in Science Module in GTB
- Verified K-39 and Rb-87 magnetic trapped mixtures in EMTB
- Tuning K performance to continue in EMTB and during Flight System's commissioning phase



Flight System magnetic trap of K-39 atoms

Sympathetic cooling in the Flight Science Module in CAL's GTB



Some Key Issues Resolved Prior to Delivery

- May 2017: The investigation and repair efforts for the failed atom-chip breakout board for the flight system. Here, poor workmanship of the CQ header pin connectors caused multiple open connections between the BoBs and the atom chip. Corrective action was to re-design the header-pin connectors for Science Modules 1 & 2.
- May 2017: Master Lock Performance anomaly investigation. CAL team was augmented by a Tiger Team of experts from across the Lab.
  - The end-to-end system performance appears was acceptable for it to be used as is, albeit with limited margin.
  - In the process we discovered other issues and corrected them which included:
    - SW modifications and improvements
    - Cabling enhancements
    - Grounding understandings
- July 2017: In response to the FSA-1B failure, we redesigned the LOS plates with appropriate components to bring the outputs to the Science Module inline with requirements. We also reworked many of the fiber connections at Coastal and validated that the LOS end-to-end subsystem satisfies all the specifications.
- Aug 2017: The spontaneous PXI reboot issue in the flight system. We identified the source of the issue and modified the connectors/cables in the flight system to resolve this issue.

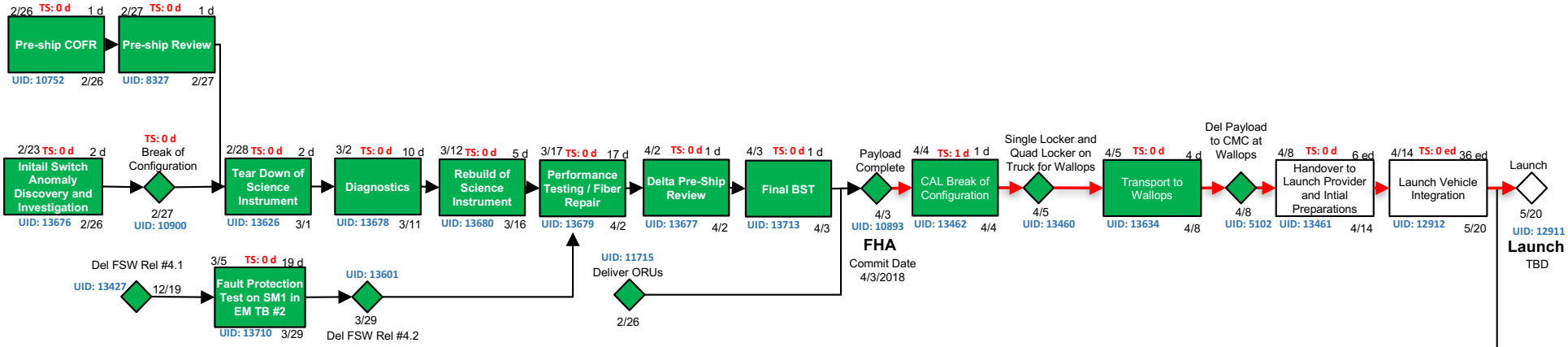
Some Key Issues Resolved Prior to Delivery

- Sept 2017: Fall times for the MOT, bias, and transfer coils were found to be too slow for achieving the CAL atom number and temperature requirements. A proposed solution both in the circuitry and the cabling was adopted to achieve the required fast turn-off of these drivers.
- Nov 2017: After the Non-Op Thermal Test, it was found that one of the cameras and the FPGA2 trap RIO was not working.
  - It was found that a fuse in the camera blew. This resulted in developing an inrush-limiter circuit to protect the fuses in the flight cameras.
  - It was found that the communication channels to FPGA2 were faulty due to failed connectors at the PXI. Corrective action resulted in replacing all 68-Pin VHDCI connectors in the flight system with solder-type connectors.
- Jan 2018: Prior to the Random Vibe and Thermal-OP environmental campaigns, communication to FPGA2 was again found to be intermittent. We found that the reworked connectors had been cleaned improperly to remove residual flux on the connectors.
- Feb 2018: Post Environments: 767nm Agiltron switches-3A & 3B failure. Corrective action was to replace both switches with up-screened switches that had been operating in the test beds for an acceptable period of time.
  - Forced tear down and rebuild in last month

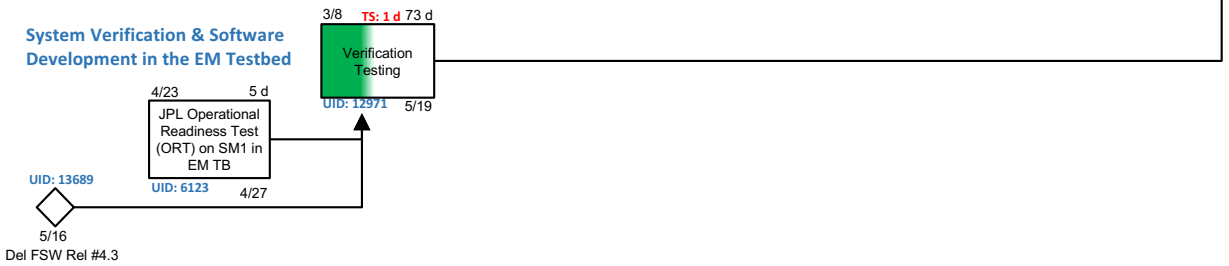
CAL Top Level Schedule

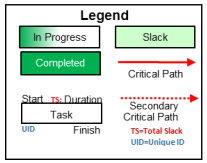
Status through
4/3/18
Produced 4/3/2018

Venue 1: Flight Quad Locker (QL)



Venue 2: EM Test Bed

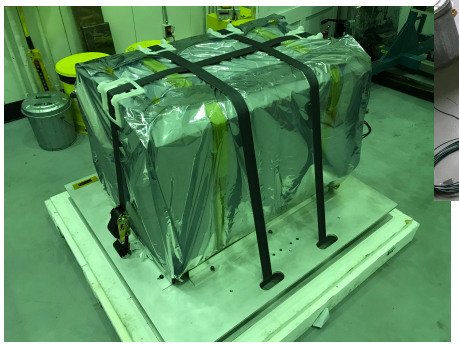




Instrument Transport from JPL to Wallops

All HW transported via 20’ FedEx Custom Critical vehicle with air ride suspension and cargo environment temperature control (65F).

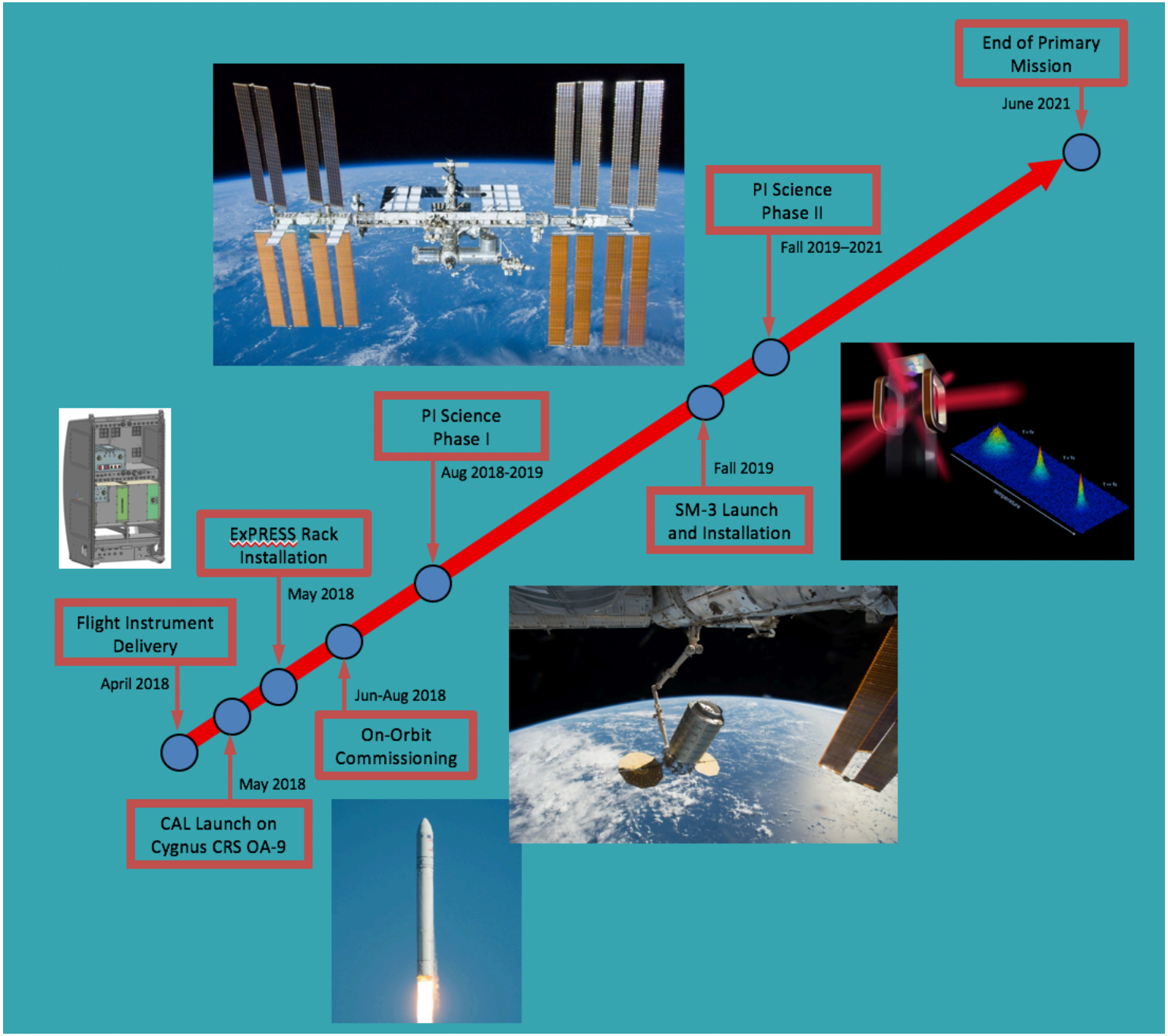
- **ORUs** transport to JSC (no escort) – Cargo packed in loaner DCTB inside padded hard case. On-dock: 2/28/2018
- **SL, QL & associated interlocker components** transport to Wallops (w/ JPL 3-officer security escort). On-dock: 4/8/2018
  - Transport vehicle to be loaded with SL container at rear of vehicle.
  - SL container to be delivered to Bldg F7
  - QL container to be delivered to Bldg H-100



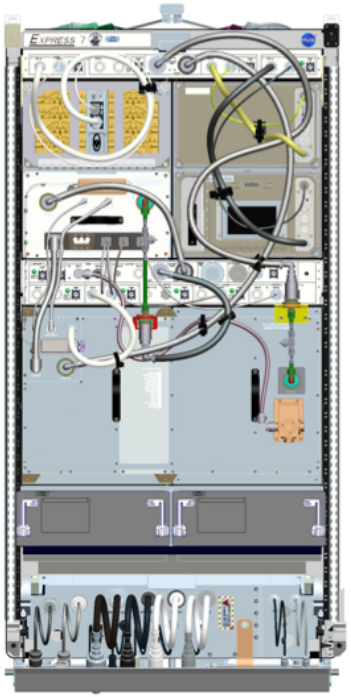
CAL Instrument Delivery Timeline

L Minus (days)	Day	Date	Action
46	Wed	4/4/18	**CAL break config** by 6AM. 2-phase fill, prep lockers and move to high bay.
45	Thu	4/5/18	Ion pump power off. Complete SL & QL shipping container integration
45	Thu	4/5/18	Load SL container w/ additional cargo. Add acceleration sensors to both lockers. Load vehicle.
45	Thu	4/5/18	**SL & QL containers depart JPL by 8PM PDT**. 60hrs transit time (FedEx est).
42	Sun	4/8/18	**SL & QL arrive at Wallops by 8AM EDT** w/ cables, fibers, MTL jumpers
38	Thu	4/12/18	Wallops - SL, DCTB, and other cargo packaged in 10.0 CTB by CMC
36	Sat	4/14/18	Wallops - Clamshell rolled 90 deg onto pallet
36	Sat	4/14/18	Wallops - Load clamshell into Cygnus - bldg H100
36	Sat	4/14/18	Wallops - Load M10.0bag into Cygnus - bldg H100
32	Wed	4/18/18	Wallops - PCM Rotate vertical for SM mate???
13	Mon	5/7/18	Wallops - PCM Rotate horizontal in HIF
2	Fri	5/18/18	Antares rotate to vertical at pad
0	Sun	5/20/18	Launch OA-9
-4	Thu	5/24/18	ISS berth
-5	Fri	5/25/18	Ingress
-8	Mon	5/28/18	Fiber Practice Session
-9	Tue	5/29/18	Instrument Install
-10	Wed	5/30/18	Instrument first power on
	Wed	8/29/18	Instrument Assessment and Turnover to Science Operations

CAL Mission Timeline

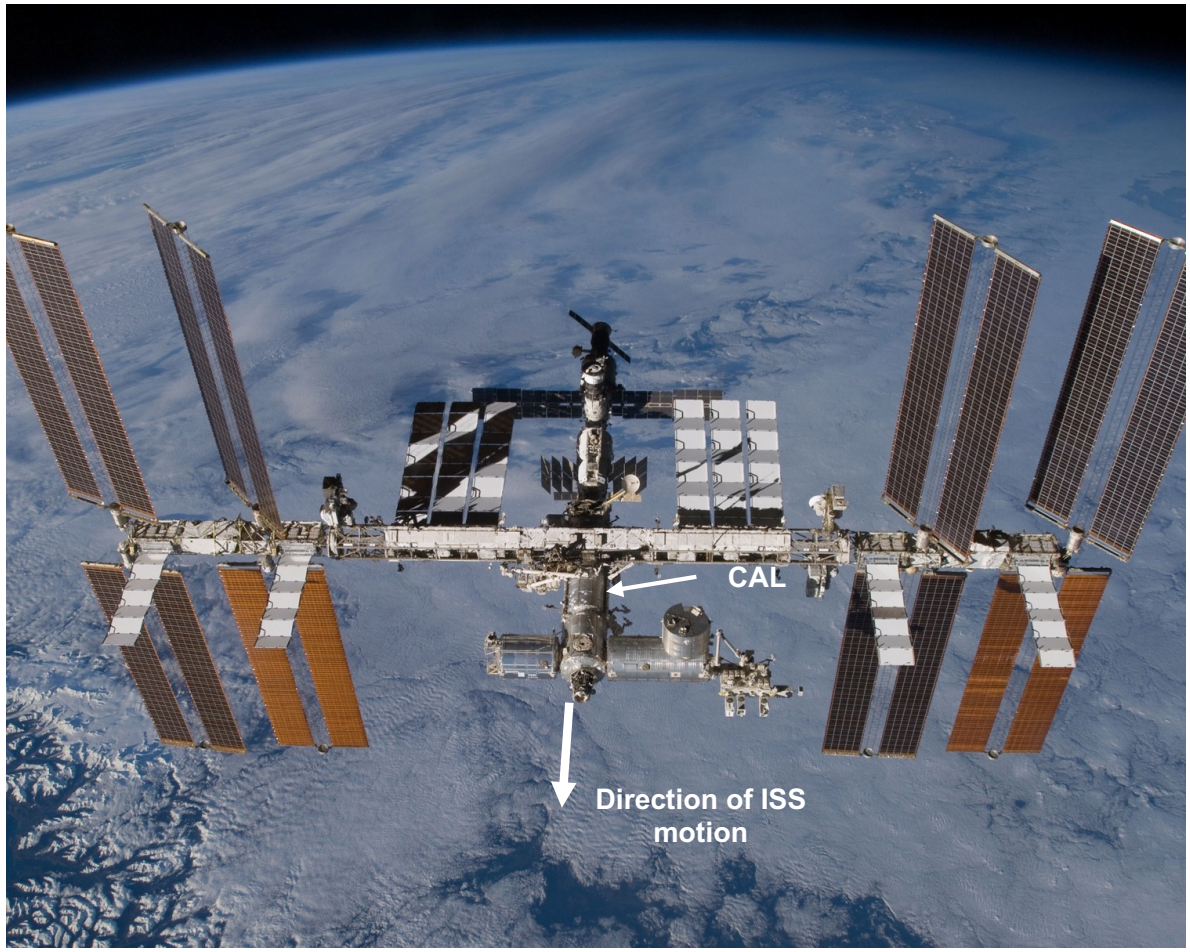


Loading into Cygnus Vehicle & ISS Installation



Instrument Install Ops Plan

- Install procedure developed by PD and astronaut office
- CAL instrument to be installed by two crew members
- PD will be on Space-to-Ground voice loop for direct communication throughout install process
- HD over the shoulder video will stream entire install process



CAL Mission Operations

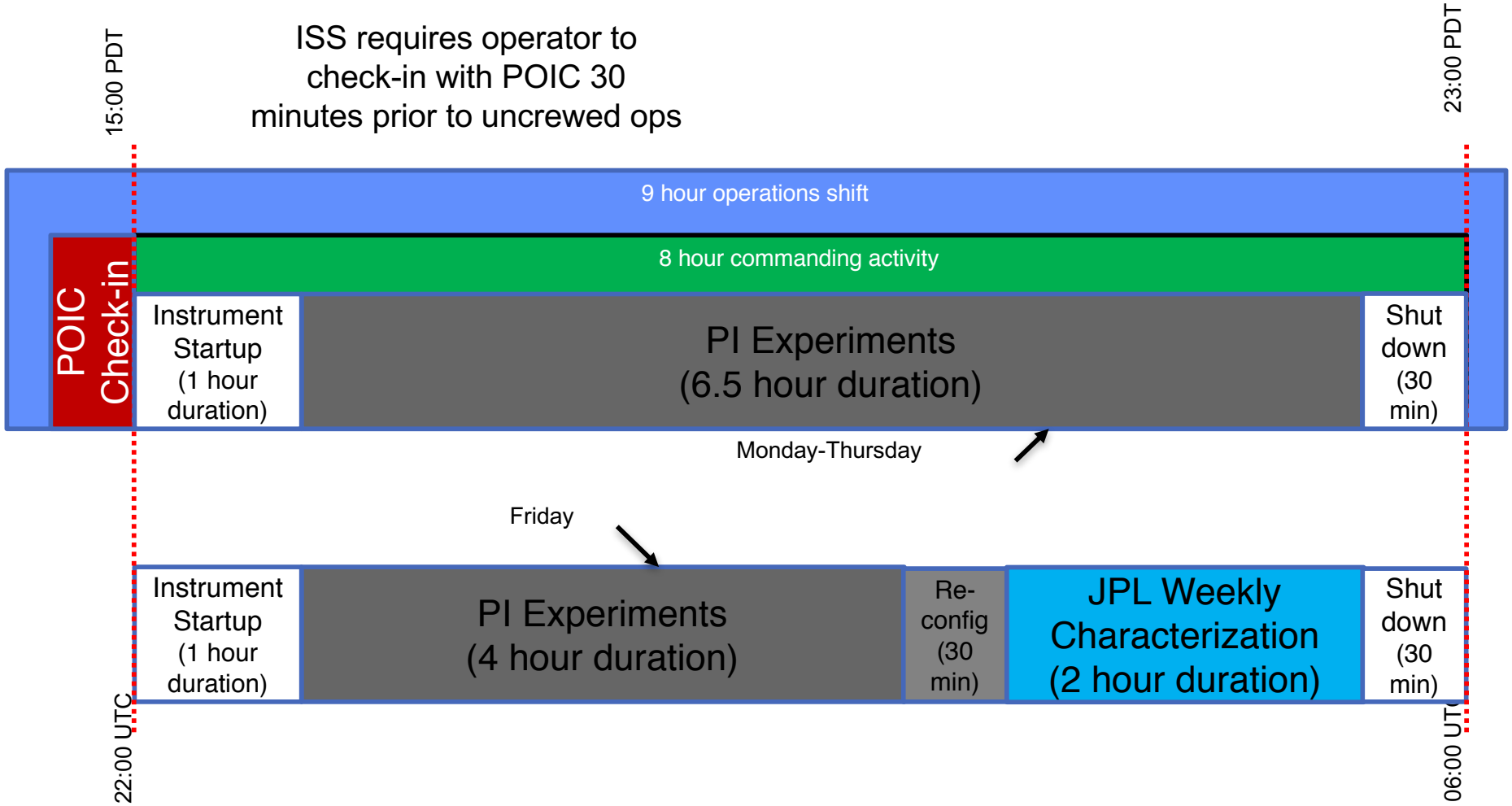
- Flight Software version 4.2.4.5 is the final flight version prior to launch:
  - Includes autonomous fault protection, RIO and TAD telemetry, and improved Holzworth upload speed and buffer status monitoring
  - Major improvements to master laser control, including better lock reliability and processing speed
- Ops team readiness:
  - Team has completed ISS-required training sessions
  - Team participated in ISS voice loop simulation
- Network paths between JPL and Huntsville Operations Support Center (HOSC) have been set up and tested
  - Realtime telemetry flow
  - Realtime video feed (used for Install and ORU activity only)
  - Science data downlink
- Have exchanged example science data files with PSI
- Operational Readiness Test involving JPL Science Team to be conducted the week of 4/23/18

CAL Mission Operations

- CAL project has 3 dedicated seats
- Already used for ISS sim, multiple HOSC network tests

- Earth Orbiting Missions Operation Center
- Facility shared by several JPL missions
- Has TVs and projectors for viewing realtime ISS video feed
- Has attached conference room

Daily Experiment Execution



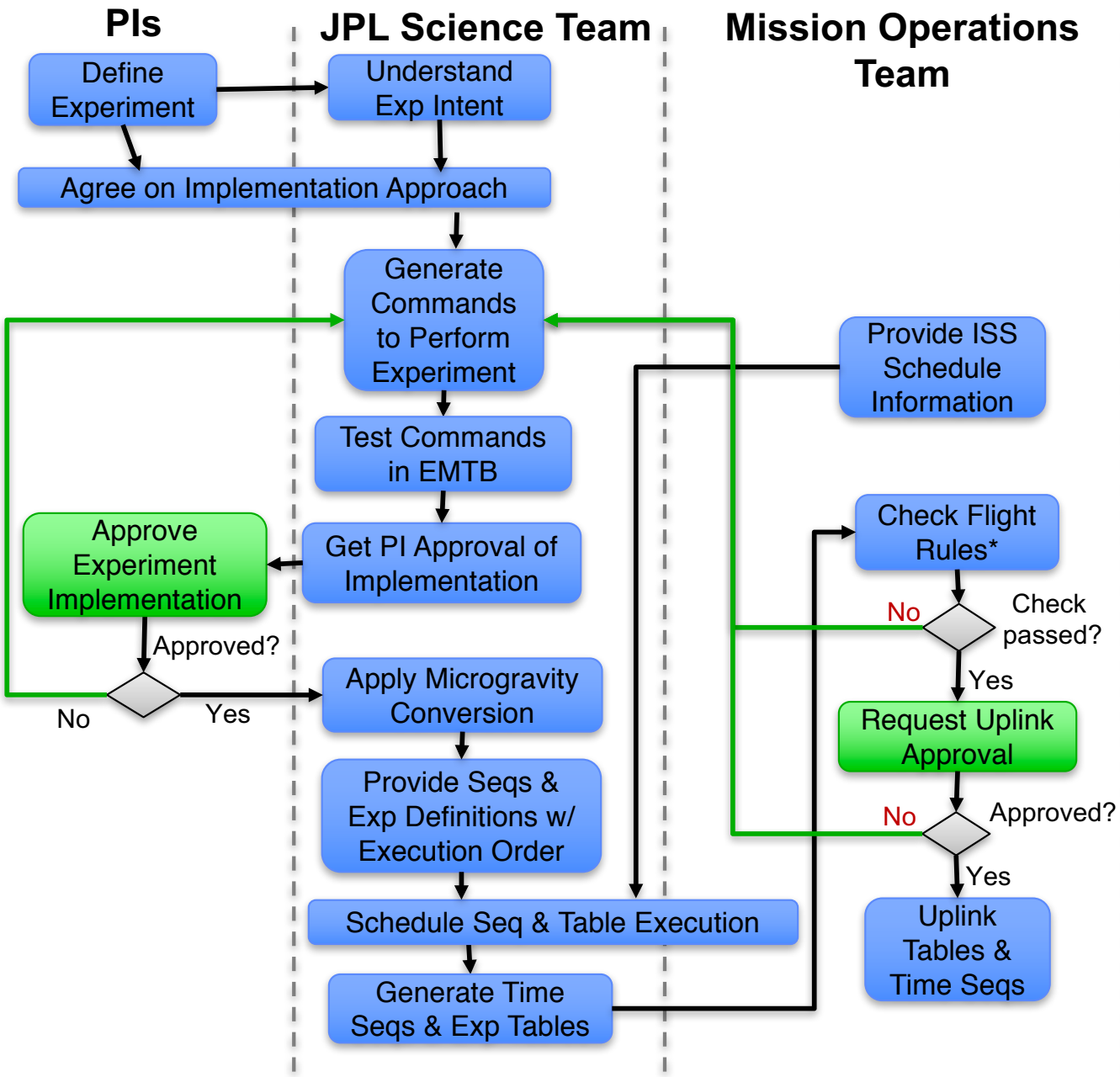
Startup includes instrument power on and setup for first PI of the night

Shutdown includes powering instrument off and leaving in a safe state until next ops period

POIC - ISS Payload Operations Integration Center, Huntsville, AL

Back up

Pre-Uplink Functional Responsibilities



Six-Week PI Rotation

	Week 1					Week 2					Week 3				
	M	Tu	W	Th	Fri	M	Tu	W	Th	Fri	M	Tu	W	Th	Fri
Flight Instrument	PI-1	Eng	PI-1	Eng	PI-1 Eng	PI-2	PI-1	PI-2	PI-1	PI-2 Eng	PI-3	PI-2	PI-3	PI-2	PI-3 Eng
EMTB	PI-3	PI-2	PI-3	PI-2	PI-3	PI-4	PI-3	PI-4	PI-3	PI-4	PI-5	PI-4	PI-5	PI-4	PI-5

	Week 4					Week 5					Week 6				
	M	Tu	W	Th	Fri	M	Tu	W	Th	Fri	M	Tu	W	Th	Fri
Flight Instrument	PI-4	PI-3	PI-4	PI-3	PI-4 Eng	PI-5	PI-4	PI-5	PI-4	PI-5 Eng	Eng	PI-5	Eng	PI-5	Eng
EMTB	Eng	PI-5	Eng	PI-5	Eng	PI-1	Eng	PI-1	Eng	PI-1	PI-2	PI-1	PI-2	PI-1	PI-2

- Each PI will have two weeks of test time in EMTB, followed by two weeks of operations on ISS. Project Scientist to decide order of PI experiments.
- One PI per venue per day: each will get a full day, minus setup and shutdown time (6.5 experiment hours per day dedicated to a single PI)
- PIs will operate every-other work day. This allows a day to review data in between each operational shift and removes time lost to handovers between PIs mid-shift.
- The last part of each Friday is engineering time to allow the JPL team to perform weekly baseline system test for performance trending
- Total: 30 experiment hours over two weeks per PI; JPL gets two weeks of performance characterization time every 5 weeks, plus 2 hours every Friday